Assessment of Hazards to Non-Native Mongooses (*Herpestes auropunctatus*) and Feral Cats (*Felis catus*) from the Broadcast Application of Rodenticide Bait in Native Hawaiian Forests

Peter A. Dunlevy
USDA APHIS Wildlife Services, National Wildlife Research Center, Hawai'i Field Station, Hilo, Hawai'i
Earl W. Campbell III
USDI Fish and Wildlife Service, Pacific Islands Ecoregion, Ecological Services, Honolulu, Hawai'i

Abstract: Primary non-target hazard assessment can be separated into two basic components: bait acceptance and toxicity. This bait acceptance study investigates the potential primary non-target hazard (direct consumption of bait pellets) that the broadcast application of rodenticide bait may pose to non-native feral cats and mongooses. The study was conducted in 4 different forest habitats in Hawaii using 2 different commercial formulations of placebo bait pellets. We documented vertebrates that came to placebo bait pellets at bait monitoring stations to assess bait acceptance. Bait pellets were monitored at each site using 40 infrared (IR) monitors/data loggers and weatherproof automatic cameras. During the 80 days of the study, cameras operated for 76,800 hours and recorded 21,211 slides of vertebrates at bait stations. Rodents, the target species, were the largest group, documented at stations in 98.98% (n = 20,994) of these photographs. Feral cats were detected in 0.09% (n = 20) and mongooses in 0.46% (n = 97) of the slides of vertebrates at bait pellets. The 117 photos of feral cats and mongooses represent 44 occasions where these predators encountered bait pellets; in 14 of these the bait was eaten. These data suggest that the primary hazard to non-native feral cats and mongooses from the broadcast application of pelletized rodenticides is very low. Thus, this study should support the effort to obtain regulatory approval for the broadcast application of rodenticide bait for conservation purposes in the state of Hawaii.

Key Words: cat, *Felis cattus*, mongoose, *Herpestes auropunctatus*, non-target, primary hazard, environmental hazard assessment, invasive species, alien species, restoration ecology, recovery of endangered species, Hawaiian forest birds

Proc. 20th Vertebr. Pest Conf. (R. M. Timm and R. H. Schmidt, Eds.)
Published at Univ. of Calif., Davis. 2002. Pp. 277-281.

INTRODUCTION

Introduced rats (*Rattus* spp.) have had devastating impacts on insular ecosystems worldwide, including the Hawaiian Islands (Atkinson 1977, Buckle and Fenn 1992, Moors et al. 1992, Seto and Conant 1996). The historic introductions of these species to the Hawaiian Islands have been implicated in the extinction of numerous native plant and animal species directly through predation and indirectly via competition for habitat and food resources (Atkinson 1985). Commensal rats have contributed significantly to declines in endemic Hawaiian flora and fauna (Atkinson 1977, Baker and Allen 1976, Scowcroft and Sakai 1984, Stone 1985, Scott et al. 1986, Hadfield et al. 1993). Introduced rats spread the seeds of invasive plants and are vectors for human and animal diseases such as leptosporosis (Tomich 1986).

Rodent control is considered a high priority for many species and ecosystem restoration plans in Hawaii (Tobin 1994). Broadcast rodenticides have been used successfully to control introduced rodents for species conservation and habitat restoration in New Zealand (Miller and Anderson 1992) and could potentially be used in Hawaii. The success of New Zealand rodent control efforts (Innes et al. 1995) prompted the formation of a multi-agency rodenticide-working group in Hawaii to seek regulatory approval for the use of similar techniques in Hawaii.

Diphacinone was selected as the rodenticide to pursue for registration because of its effectiveness against rats in Hawaii (Tobin 1992), low risk to non-target species (including humans), and limited persistence in the environment (Kaukeinen 1982, Lund 1988). In 1995, collaborative efforts of the working group culminated in a statewide Environmental Protection Agency (EPA) registration of J.T. Eaton All-Weather Bait Blocks® for use in approved stations to reduce rat depredations in native Hawaiian ecosystems. At present, two 0.005% diphacinone formulations of J.T. Eaton Bait Blocks® (fish-flavored, SLN HI 970007, and peanut butter-molasses flavored, SLN HI-940001) are approved for use in protective stations for conservation purposes in the state of Hawaii. In June 1998, Hacco Inc. also obtained a similar statewide EPA registration for Ramik Mini Bars All-Weather Rat and Mouse Killer® (fish flavored, 0.005% diphacinone, SLN HI-980005).

Application of rodenticides in stations can be an effective technique for reducing rat populations in limited areas (Erikson and Halvorson 1990) but is extremely labor intensive and impractical for large areas. There is a critical need to obtain registration for a broadcast use pattern of rodenticides in Hawaiian conservation areas. Since many of the sites where native flora and fauna threatened by rodent species are in remote and rugged areas with limited access, the only cost-effective method for rodent control in these sites is the broadcast application of rodenticide bait (Moors et al. 1992, Tobin 1994). A statewide, Special Local Needs 24(c) EPA registration of Eaton and Hacco pelletized diphacinone bait formulations is being pursued for broadcast application in Hawaii.

To obtain regulatory approval for the broadcast application of diphacinone bait pellets for conservation purposes, primary hazard to non-target species must be determined. This study evaluated the direct non-target hazards of two bait formulations of pelletized diphacinone rodenticides to feral cats (*Felis catus*) and mongooses (*Herpestes auropunctatus*). A separate discussion of avian non-target issues is in press. The two primary components of non-target assessment are bait acceptance and toxicity. This project monitored detections at bait in the field to identify primary non-target hazards.

METHODS

This study was conducted at four sites, three in Hawaii Volcanoes National Park on the Island of Hawaii (Kipuka Ki, Kipuka Nene and Olaa) and one in Waikamoi Nature Preserve on the Island of Maui (Figure 1). Brief descriptions of the sites are presented here. Kipuka Ki is located on the southeast slope of Mauna Loa on the island of Hawaii, in Hawaii Volcano National Park (HAVO). Kipuka Ki is a mesic forest at an elevation of approximately 1300 m. Overstory vegetation consists of tall Koa, Ohia, and soapberry forest (*Acacia koa*, *Metrosideros polymorpha*, and *Sapindus saponaria*), with some Jerusalem cherry (*Solanum pseudocapsicum*). The understory vegetation is dominated by native ferns and herbs where the forest canopy is dense and non-natives such as blackberry (*Rubus argutus*), meadow ricegrass (*Ehrharta stipoides*), and *Paspalam* spp. are common in large patches of open grassland with scattered trees.

The Nature Conservancy's Waikamoi Nature Preserve is located on the northeastern slope of Haleakal on the island of Maui. Waikamoi is a montane rainforest between 1500 and 1800 m in elevation. The overstory consists of Ohia and Koa. Understory vegetation includes *Cheirodendron* spp., *Pelea* spp., *Myrsine* spp., *Pittosporum* spp., the epiphyte *Astelia* spp., and rare and endangered *Cyanea* spp. and *Clermontia* spp. Native ferns (*Dryopteris* spp. and *Athyrium* spp.) dominate the ground cover.

Kipuka Nene is located on the southeast slope of Mauna Loa on the island of Hawaii within HAVO. Kipuka Nene is a dry shrub/grassland at approximately 1000 m in elevation. Vegetation consists primarily of grasses (Poaceae) interspersed with native and non-native shrubs and the occasional tree - Ohia and Koa.

The Olaa site is situated in the southwest corner of the Olaa Forest within the Koa Management Unit of HAVO on the southeast slope of Mauna Loa. The forest is composed of open canopy with scattered large Ohia and a dense understory of mixed native trees (*Cheirodendron* spp., *Pelea* spp., *Myrsine* spp., *Pittosporum* spp.) and tree ferns (*Cibotium* spp.). Ground cover is predominately native ferns, shrubs and sedges; however, a few non-native weeds are common, including Himalayan raspberry (*Rubus ellipticus*) and banana polka (*Passiflora mollissima*).

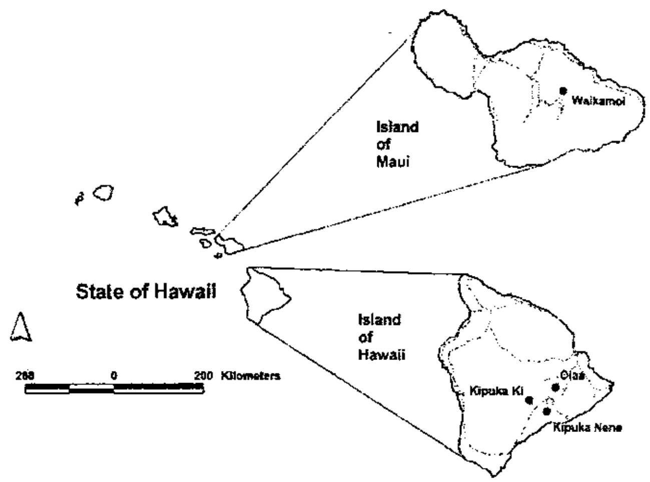

Figure 1. Locations of study sites on the islands of Hawaii and Maui.

Two replicates were conducted per site, one per bait formulation, with the exception of Kipuka Nene for which we conducted three replicates, two using the Ramik formulation and one using the Eaton formulation. Separate plots were established for each replicate. Different plots within the same site were separated by a minimum of 200 m.

Plots consisted of ten 100-m transects radiating from a central point with 36° separating transects (Figure 2). Stations were established every 25 m along each transect, for a total of 40 stations. Stations alternated along and between transects with secured and unsecured baiting. A pellet was attached with a screw to a 20 cm × 20 cm plywood board at secured bait stations, while at unsecured stations the pellet was placed directly on the ground. Each station consisted of an IR light source, an IR monitor/data logger, and a weatherproof automatic camera. The IR light source and IR monitor were staked to the ground 0.50-0.75 m apart and the camera mounted on the stake over the IR monitor/data logger. A bait pellet was placed between the IR light source and the IR monitor/data logger. Anything blocking the IR light from reaching the IR monitor/data logger triggered the IR monitor/data logger, which documented events and activated the camera based on IR monitor/data logger settings. The camera delay setting establishes criteria for the function of the camera. This setting refers to the minimum time lapse between pictures. The camera delay was set from 6 seconds to 8 minutes, depending on the activity of the station, in an effort to ensure film lasted until the next maintenance period. Stations were

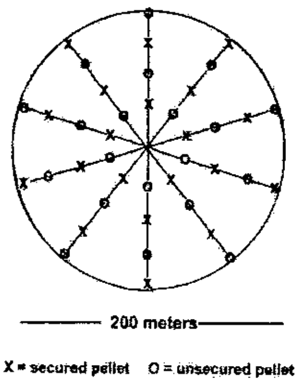

Figure 2. Plot layout.

maintained on a daily basis. Bait pellets were replenished when most of the pellet (>66%) was gone. Film and batteries were replaced each day as necessary. The alignment and positioning of monitors and cameras were inspected and tested each day. Information (bait take, number of events, number of pictures, changes made to STN-film, batteries, wire, IR source, monitor, camera) from stations was tracked on a daily basis to identify problems with equipment.

Events documented by the IR monitor/data logger are the basic unit of detections. Each event represents an occasion when the IR light was prevented from reaching the IR monitor/data logger. Events are documented in the IR monitor/data logger as an electronic record. Each event documents a code unique to each IR monitor/data logger (station), the date, time, event number, and a picture number (if applicable). Pictures are taken based on camera delay settings applied to the IR monitor/data logger. Encounters are defined as a continuous series of events and pictures that are grouped in time and space. An encounter may range from a single event and photo to multiple consecutive events and photos at the same station. An encounter presents a non-target animal with a bait pellet and the possibility of eating that pellet. Multiple pictures of the same encounter do not represent increased hazard. Once a pellet has been consumed, the opportunity for an encounter at that station ends until the next maintenance period. The encounter is the applicable unit for hazard assessment.

RESULTS

We recorded more than 167,000 events throughout the study (Table 1). Events at plots ranged from a low of 4,281 at Kipuka Ki (Rep 2) to the high of 49,374 at Olaa (Rep 8). Almost 35,000 of these events, or 20.8%, resulted in pictures. The number of pictures taken at plots ranged from 1,376 at Kipuka Nene (Rep 5) to 4,414 also at Kipuka Nene (Rep 7). The percentage of events resulting in pictures is a measure of the photographic coverage of all events at a plot. Pictures taken as a percentage of events reflects the activity at a site and the use of the camera delay setting to ensure monitoring around the clock. Pictures as a percent of events ranged from 10.17% at Olaa (Rep 8) to 45.31% at Waikamoi (Rep 3). We took 21,211 pictures of vertebrates, from 506 at Kipuka Nene (Rep 5) to 6,200 also at Kipuka Nene (Rep 7). The percentage of all pictures taken at a plot showing vertebrates varied from a low of 35.71% at Kipuka Ki (Rep 2) to the high of 71.19% at Kipuka Nene (Rep 7). Pictures not resulting in vertebrate detections were attributed to invertebrates, high wind, heavy rain, and equipment failures.

The vast majority of photographs of vertebrates at bait (N = 21,211) were the target species of rodents 98.98% (n = 20,994) (Table 2). Mongooses and feral cats appeared in 0.46% (n = 97) and 0.09% (n = 20) photographs of vertebrates at bait, respectively. There were 99 events associated with mongoose detections, producing 97 slides of mongooses at bait. This represents 39 encounters of mongooses with bait pellets (Table 3), of which 13 (33%) resulted in pellets being eaten. One plot, Kipuka Nene (Rep 7) accounted for 71 of the slides of mongooses at bait, 17 encounters of mongooses with bait, and 11 instances of bait consumption. One day at this plot produced 53 slides of 9 encounters, likely the same animal, and 7 of these pellets were eaten.

Table 1. Summary of events, all pictures, and pictures of vertebrates at bait monitoring stations.

Site	*Rep*	*Bait*	*Dates*	*Days*	*Events*	*Pictures* All (*)	*Pictures* Vertebrates (**)
Kipuka Ki	1	Ramik	27 Sept 00 - 5 Oct 00	9	6,118	2,400 (39.23)	1,171 (48.79)
	2	Eaton	23 Oct 00 - 31 Oct 00	9	4,281	1,879 (43.89)	671 (35.71)
Waikamoi	3	Eaton	17 Nov 00 - 27 Nov 00	10	9,106	4,126 (45.31)	2,589 (62.75)
	4	Ramik	18 Jan 01 - 26 Jan 01	9	17,124	4,645 (27.13)	3,183 (68.53)
Kipuka Nene	5	Ramik	11 Apr 01 - 18 Apr 01	8	4,737	1,376 (29.05)	506 (36.77)
	6	Ramik	23 Apr 01 - 30 Apr 01	8	27,374	4,939 (18.04)	3,206 (64.91)
	7	Eaton	12 Jun 01 - 20 Apr 01	9	32,046	6,200 (19.35)	4,414 (71.19)
Olaa	8	Ramik	25 Jun 01 - 3 Jul 01	9	49,374	5,020 (10.17)	3,020 (60.16)
	9	Eaton	10 Aug 01 - 18 Aug 01	9	17,248	4,236 (24.56)	2,415 (57.86)
Sub-totals		*Ramik*		*43*	*104,727*	*18,380 (17.55)*	*11,086 (60.32)*
		Eaton		*37*	*62,681*	*16,441 (26.23)*	*10,125 (61.58)*
Total				***80***	***167,408***	***34,821 (20.80)***	***21,211 (60.91)***

* percent of events resulting in pictures
** percent of all pictures documenting vertebrates

Table 2. Number and percent of vertebrate detections by location, bait type, and species.

				Pictures of Vertebrates			
				Target Species	*Non-target species*		
Site	Rep	Bait	Days	Rodents (**)	Mongooses (**)	Cats (**)	Non-native birds (**)
Kipuka Ki	1	Ramik	9	1,077 (91.97)	2 (0.17)	0	92 (7.86)
	2	Eaton	9	652 (97.17)	2 (0.30)	17 (2.53)	0
Waikamoi	3	Eaton	10	2,568 (99.18)	17 (0.66)	1 (0.04)	3 (0.12)
	4	Ramik	9	3,177 (99.81)	0	2 (0.06)	4 (0.13)
Kipuka Nene	5	Ramik	8	506 (100.00)	0	0	0
	6	Ramik	8	3,204 (99.91)	2 (0.06)	0	1 (0.03)
	7	Eaton	9	4,342 (98.38)	71 (1.62)	0	0
Olaa	8	Ramik	9	3,019 (99.97)	1 (0.03)	0	0
	9	Eaton	9	2,449 (99.92)	2 (0.08)	0	0
Sub-totals		*Ramik*	*43*	*10,983 (99.06)*	*5 (0.05)*	*2 (0.02)*	*97 (0.87)*
		Eaton	*37*	*10,011 (98.89)*	*92 (0.90)*	*18 (0.18)*	*3 (0.03)*
Total			***80***	***20,994 (98.98)***	***97 (0.46)***	***20 (0.09)***	***100 (0.47)***

** percent of all pictures documenting vertebrates

Table 3. Number of events, pictures, encounters, and bait pellets consumed for mongooses and cats at bait monitoring stations.

				Mongooses				Cats			
Site	Rep	Bait	Days	Events	Pictures	Encounters	Pellets eaten	Events	Pictures	Encounters	Pellets Eaten
Kipuka Ki	1	Ramik	9	2	2	2	0	0	0	0	0
	2	Eaton	9	2	2	2	1	17	17	2	1
Waikamoi	3	Eaton	10	17	17	13	1	1	1	1	0
	4	Ramik	9	0	0	0	0	2	2	2	0
Kipuka Nene	5	Ramik	8	0	0	0	0	0	0	0	0
	6	Ramik	8	2	2	2	0	0	0	0	0
	7	Eaton	9	73	71	17	11	0	0	0	0
Olaa	8	Ramik	9	1	1	1	0	0	0	0	0
	9	Eaton	9	2	2	2	0	0	0	0	0
Sub-totals		*Ramik*	*43*	*5*	*5*	*5*	*0*	*2*	*2*	*2*	*0*
		Eaton	*37*	*94*	*92*	*34*	*13*	*18*	*18*	*3*	*1*
Total			***80***	***99***	***97***	***39***	***13***	***20***	***20***	***5***	***1***

Waikamoi (Rep 3) accounted for a further 17 detections and 13 encounters, one resulting in bait consumption. Together these two plots made up more than 75% (n = 30) of mongoose encounters throughout the study and 92% (n = 12) of bait consumption by mongooses. There were 21 encounters at secured stations and 18 encounters at unsecured stations. Time of detection for mongooses ranged from 07:30 - 19:01 and the average detection time was 14:24. Of the 39 mongoose encounters, 20 occurred as the first event recorded after station maintenance. Mongoose encounters with bait occurred on 20 of the 80 days of the study and ranged from 1 to 9 per day. The Eaton bait pellets accounted for 34 of these encounters and all pellets that were eaten. Ramik bait pellets were implicated in 5 encounters; mongooses ate none of these bait pellets.

There were 20 events associated with cat detections, producing 20 slides of feral cats at bait. This represents 5 encounters of feral cats with bait pellets, of which one (20%) encounter resulted in a single Eaton bait pellet being eaten. Kipuka Ki (Rep 2) recorded the highest percentage of cat detections 2.53% (n = 17) for the study. The 17 slides represent two distinct encounters of feral cats with bait pellets. One of these encounters resulted in the only bait pellet being eaten by a cat. Two encounters were at secured stations and three were at unsecured stations. Cat encounters with bait occurred on 4 of the 80 days of the study. There were two in the same plot on subsequent days, two in the same plot on the same day, and a single encounter at a third plot. Time of detection for feral cats ranged from 02:06 - 18:52 and the average detection time was 13:48. Monitoring stations with Eaton pellets recorded 90% (n = 18) of all cat detections. The remaining 10% (n = 2) were detected at Ramik pellets. Two encounters in the same day at Waikamoi (Rep 4) were of the same individual, which did not consume the bait.

DISCUSSION

Detections at bait were predominately the target species of rodents, 98.98% (n = 20,994). This corresponds to earlier work (Dunlevy et al. 2000), which determined the efficacy of the broadcast application of pelletized bait to control rodents in native Hawaiian forests. Efficacy is the issue for target species while hazard is the concern for non-target species. Mongooses and feral cats were detected at bait in 0.46% (n = 97) and 0.09% (n = 20) of photographs, respectively. The small percentage of detections of feral cats and mongooses represent an even smaller number of actual encounters of these species with bait pellets. Further reducing hazard for feral cats and mongooses are the low percentage of bait consumed during these encounters. More cat and mongoose encounters were observed with Eaton bait. Eaton bait was the only formulation eaten by these non-native predators.

This study suggests that the hazard associated with the primary exposure of feral cats and mongooses to pelletized diphacinone bait is very low. Primary hazards will differ with the toxicant used in a bait formulation (e.g., brodificoum, bromadiolone, or chlorophacinone). This study does not address secondary hazards. This data supports the multi-agency effort to obtain regulatory approval of the broadcast application of diphacinone bait to protect native resources in conservation areas in the state of Hawaii.

ACKNOWLEDGEMENTS

We thank Lori Oberhofer, Charlotte Forbes, and Zachary Nelson for assistance in the field. The State of Hawaii, Division of Forestry and Wildlife, and the Nature Conservancy of Hawaii provided funding for the study. We also appreciate access to study sites from Hawaii Volcanoes National Park and the Nature Conservancy of Hawaii.

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